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TRENDS IN MODERN PHYSICS[1]

By Professor **ALLAN FERGUSON**

PRESIDENT OF SECTION A—MATHEMATICAL AND PHYSICAL SCIENCES

OUR section has suffered heavy losses in the twelve months that have passed since the Norwich meeting, and it is fitting that we should here pay due honor to the memories of McLennan, Glazebrook, Petavel and Pearson, who have, each in his own characteristic fashion, played so great a part in the advances made during this century.

The genius and vigor of Sir John McLennan were quick to seize on and to develop those ideas which were fermenting at Cambridge in the last years of the nineteenth century and to impress on them a character peculiarly his own. His energy and versatility are shown equally in his early studies of penetrating radiation, in his discovery of the single line spectrum of zinc and cadmium, in his later work on the spectrum of the aurora and the nature of the famous green line and in those studies of supraconductivity to which his last years in Toronto were given. His return to England found him unconquerably young in spirit and prepared to play his part in important investigations in radium beam therapy. He presided over the deliberations of this section at the Liverpool meeting of 1923, and those of us who were present at that meeting have vivid memories of an address which reviewed some of the major problems of atomic structure—an address which, the latest word on the matter in 1923, reads to-day as an ancient tale. The laboratory at Toronto which bears McLennan's name bears witness also to his genius as a leader of research and to his gifts as administrator and director.

Sir Richard Glazebrook belonged to the elder generation—he presided over Section A so long ago as 1893—and to the last occupied himself with certain aspects of those problems of macroscopic physics which dominated the science of his century. His early papers on the Fresnel wave-surface are admirable examples of accurate work accomplished with the aid of simple

[1] Concluding portion of an address given at the Blackpool meeting of the British Association for the Advancement of Science.

apparatus; and his experiments on the relation between the British Association unit of electrical resistance and the absolute unit marked the first step on a lifelong journey. *Felix opportunitate mortis,* illness was spared him, and death laid a kindly hand on his shoulder while he was still in the full tide of mental activity, still pursuing those studies which had been his companions for more than half a century. The National Physical Laboratory, which, opening in 1902 with two departments and a staff of twenty-six, had in ten years expanded to eight departments and a staff of 126, is Glazebrook's enduring monument.

The work of this great laboratory, stimulated by the conditions of the world war, was further developed by Sir Joseph Petavel; under his guidance the laboratory has steadily grown in prestige and in the range of its activities, which now demand the services of a staff of nearly seven hundred. In the counsels of our association, Sir Joseph Petavel ranked as an engineer—he presided in 1919 over the work of Section G—but we of this section are not unmindful of his contributions to physical science: of his studies of the emissivity of platinum at high temperatures, of the effect of pressure on arc spectra, of his interest in the problem of aeroplane stability.

Genius, both in its creative aspect and on that side which has been condensed by Edison into a whimsical phrase, marked all to which Karl Pearson put his hand. His ordered development of statistical theory, wherein new light is shed on the fundamental problems of frequency distribution, correlation and probable errors, formed a firm foundation number (k) which quantizes the angular momentum, and what is called the radial quantum number, the sum of the two being set equal to the total quantum number (N).

But the theory in this form was quite inadequate to cope with any system more complex than a single electron system. To deal with these more complex systems, quantum notions were extended on quasi-empirical lines and resulted in what may be called a vector model of the atom in which were visualized the possibility of electron and nuclear spins, with further possibilities in the way of quantization and quantum numbers. If these quantum numbers are shared between the satellite-electrons of an atom in such a way as to agree with an empirical exclusion principle which states that *no two electrons in an atom may have all their quantum numbers identical,* we may arrive at a distribution of the satellite-electrons as regards their energy-levels which gives a model capable of explaining many complex spectroscopic (and other) facts.

But space presses and we must return, in this rapid survey, to a consideration of that dualism of outlook which appeared so early in the story of twentieth-century physics. The discovery of the Compton effect further emphasized this corpuscular aspect of ra[di]ation.[2]

Suppose we carry this dualism into concepts th[at] are fundamentally corpuscular and assert that matt[er] may have a wave aspect? This is the notion put fo[r]ward by Louis de Broglie, who postulated that, as[so]ciated with a particle having momentum mv, there i[s a] wave of wave-length λ given by $\lambda = h/mv$. As ra[di]ation which shows the fundamental wave-proper[ty] diffraction also exhibits corpuscular properties, [as] electrons which are conceived primarily as corpuscul[ar] may be expected to exhibit wave-properties; and th[ey] do so. If a beam of electrons be passed through th[in] foil, diffraction phenomena are observed which [are] perfectly consistent with the wave-length postulat[ed] by de Broglie. If, moreover, leaving the sub-atomi[c] world, we deal with *molecular rays* of hydrogen [or] helium, we may allow them to be reflected from [a] crystal surface and may observe diffraction phenome[na] consistent with a de Broglie wave-length of the rig[ht] magnitude; *and we may collect the reflected waves [in] an ordinary gas.*

But all this merely emphasizes the dualism of th[e] wave and corpuscular aspects of matter—a dualis[m] which is now disappearing under the analysis of th[e] last few years. The analysis, which is essentially mathematical, has introduced the notion of prob[a]ability into our estimates, say, of position. We de[-]scribe the wave which accompanies a corpuscle by means of an equation which will contain an expressio[n] for the amplitude of the wave; and the amplitude at any point gives us a measure of the probability of finding the corpuscle at that point; if the amplitude vanishes anywhere the probability of finding the cor[-]puscle at that point vanishes also. The concept of an electron as a definite entity at a definite point in space is replaced by a probability pattern which, very dense in a certain locality, rapidly thins as we move away from that locality. In fact, if we fix our attention on the densest part of a given pattern, the probability of finding an electron at a distance of 10^{-13} cm therefrom becomes vanishingly small, and most of us may be con[-]tent to use the concept of an electron almost in our accustomed manner, realizing that it has become a little fuzzy at the edges.

Despite the impending disappearance of this dual[-]ism, the story of the discovery of sub-atomic particles

[2] When x-rays are scattered by impact with the more lightly bound electrons in an atom, the radiation scattered at an acute angle has a smaller frequency than the fre[-]quency of the incident radiation, a simple explanation of the change being at once forthcoming if the problem is treated in the manner of the treatment of the impact of elastic spheres. Thus a light quantum hn communicates kinetic energy to an electron by impact. The scattered quantum hn' will have less energy, and hence n' will be less than n.

is most easily told in particle fashion. The discovery of the electron is now more than a generation old, as is the discovery of the α-, β- and γ-rays of radium, and the α-rays or particles—fast-moving helium nuclei—provided an atomic projectile which in the hands of Rutherford became a most potent weapon for exploring the intricacies of atomic structure.

Electrons, α-particles and protons are electrical in origin; they may therefore be deflected by electrostatic fields. They move and so constitute an electric current; they may, therefore, be influenced by magnetic fields. Information concerning their charges and masses may therefore be deduced from their behavior when subjected to such fields. Further, special means have recently been devised for the generation of controlled fields of high potential which may be used to accelerate charged particles subjected to their influence. In this manner it has been found possible to produce swift protons which may be used to bombard various elements. We can in fact now load, aim and discharge our atomic rifle almost at will, and with very remarkable results. For example, the bombardment of lithium with high velocity protons results in the formation of α-particles, a process which may be described by saying that the lithium nucleus whose atomic mass-number is 7 when bombarded by a proton whose mass-number is 1, gives rise to two α-particles, each of mass-number 4.

With this advance in technique has come a corresponding advance in discovery. Thus the bombardment of a light element such as beryllium by α-particles results in the production of γ-rays together with a radiation which does not ionize the air through which it passes, but may be recognized by its effect on the nuclei which it itself bombards, producing, as it does, ionization tracks due to the protons expelled from these nuclei. We have to deal, then, with a massive uncharged particle, whose mass may be deduced from a study of the tracks made by the nuclei with which it collides. The mass of the particle is very nearly equal to that of the proton, and it has been called the *neutron*.

For long it has been known that radiation of high penetrating power exists in the atmosphere, a radiation which increases in intensity, that is, in its power to discharge an electroscope, with increasing height. This is the so-called cosmic radiation, which may be assumed to have its origin in interstellar space. Investigations on cosmic radiation, using the Wilson cloud chamber placed in a strong magnetic field, disclosed the fact that when cosmic radiation passed into such a chamber tracks were produced, some curved in one direction, some in the opposite sense. This opposite curvature might be produced by a reversal of the sign of the charge or it might be due to the fact that the particle was moving in a direction opposite to that of its fellows of opposite curvature. It was not difficult to rule out this latter possibility, and we are thus provided with another sub-atomic entity of mass equal to that of the electron, and with a positive charge equal to the electronic charge.

The identification of heat and energy—a commonplace to-day—was not established without difficulty. The twentieth century has seen a possibly more remarkable identification—that of mass and energy—an identification which was made, to within a factor of $\frac{3}{4}$, by Hasenöhrl and was put forward in its present form in 1905 by Einstein. In this form the energy (E) possessed by a mass (m) is given by $E = mc^2$, where c is the velocity of light. Increase of mass of a system means increase of energy and conversely. And if mass be destroyed a corresponding amount of energy appears as radiation, if conservation laws hold. These conservation laws have been arrived at from a study of large-scale phenomena, and there is no *à priori* reason why they should be expected to hold when applied to atomic happenings far outside the perceptual scheme of things. Indeed, one is tempted to ask, Why should the concept of energy have any meaning, let alone any validity, when applied to such systems? The necessary and sufficient answer is the pragmatic one.

The possible invalidity of this law of conservation is no new concept. Twelve years ago Bohr and his colleagues put forward a theory in which an atom in an excited state emits radiation continuously, radiation which, falling on another atom, may make more probable its transition to a higher energy-state. It may be shown that such a theory involves a contradiction of the conservation law in single atomic processes, and experiments carried out to test the theory were best explained on the assumption of conservation.

Recently the supposition of conservation which, as we have seen in the Compton effect, was invoked to explain the changes of frequency involved in the impact of a light quantum and an electron, has again been called into question as a result of experiments made, using modern counting apparatus, on the scattering of γ-rays.

If we apply the conservation laws to nuclear transformations involving protons and neutrons we find that energy is conserved quantitatively, the kinetic energy liberated in a reaction being accurately accounted for by the disappearance of mass which occurs. It is different when we consider atomic processes which involve high speed particles—electrons, say, moving with velocities comparable with that of light. Such processes are not in agreement with the conservation principle, and to pull them into line a

new particle, the neutrino, has been introduced, possessing no charge and, if Fermi be right, a negligible mass. Such a particle is not likely to be detected by direct experiment; its principal function is to "explain" continuous β-ray spectra.

Obviously we have a considerable range of choice in our atomic building materials, and the supposition that the nucleus is composed of protons and electrons in suitable numbers may need modification. The α-particle, long described as made up of four protons and two electrons, may also be considered as composed of two protons and two neutrons, and there are good reasons for this supposition. But whether the neutron is an elementary particle and the proton may be written as neutron + positron, or whether we have more justification for considering the neutron as proton + electron are matters which can not be discussed in detail here.

One of the most remarkable of the discoveries of recent years has been that of artificial radioactivity. Rutherford's fundamental discovery of 1919 was that transmutations may result from bombardment by α-particles. Thus, for example, the bombardment of nitrogen by α-particles results in the transmutation described by the nuclear equation

$$N_7^{14} + He_2^4 \rightarrow O_8^{17} + H_1^1$$

[Read: The nitrogen nucleus of atomic mass-number 14 and atomic number 7 when disintegrated by an α-particle yields the isotope of oxygen of atomic mass-number 17 and atomic number 8 together with a proton.]

Radioactive bodies, on the other hand, are bodies that break down spontaneously. We have various particles at hand with which to effect transformations by bombardment of nuclei, and for the most part the products resulting from such transmutations are stable. It might, however, happen that a product is produced which spontaneously disintegrates, and we then have the phenomena of artificial radioactivity. The bombardment (*e.g.*) of aluminium with α-particles resulted in the emission of neutrons (the neutron n_0^1 being a particle whose mass-number is unity and nuclear charge zero).

Hence we have

$$Al_{13}^{27} + \alpha_2^4 \rightarrow P_{15}^{30} + n_0^1,$$

the resulting product being an isotope of phosphorus. But if the bombardment ceases we find that positrons are emitted, the positron (p) being a particle of negligible mass and unit positive charge. The isotope of phosphorus produced is in fact radioactive and the nuclear equation gives

$$P_{15}^{30} \rightarrow Si_{14}^{30} + p,$$

the final product being an isotope of silicon. Bombardment by protons, neutrons or deuterons may produce disintegration products which are unstable; the unstable products resulting from bombardments by α-particles or deuterons pass over into stable species, sometimes with the emission of positrons, sometimes with the emission of electrons; this latter species of decay—the β-active species—is often accompanied by γ-radiation, so that artificially produced radioactive substances behave in the manner characteristic of natural β-active substances. Neutron bombardment, when it produces radio-elements, produces elements which are β-active.

By nothing has the world-picture of to-day been so transformed from that of a generation—nay of a decade—ago than by the introduction of the uncertainty principle and by its effect on our notions of causality.

It can be shown that of two conjugate quantities—time and energy, or position (x) and momentum (p)—the product of their uncertainties of determination can never be less than the quantum h. Thus an increase in the accuracy of the determination of one quantity necessitates a corresponding decrease in the accuracy of the conjugate quantity, and in particular the exact determination of one quantity leaves the other completely undetermined. An attempt to determine the position of a particle involves its illumination by light of suitable wave-length, and decrease of the wave-length in order to improve the definition of its position involves an increase in the magnitude of the recoil due to the Compton scattering process.

Following a suggestion of Dr. Flint, let us fix our attention on the quantities position and momentum and consider a coordinate system in which momentum (p) is plotted along one axis and position (x) along the other. The coordinate space gives us the possible simultaneous values of x and p. Suppose this space divided into rectangles each of area h. Then the uncertainty principle, which asserts that the product ($\delta x \delta p$) of the uncertainties of the determination of position and momentum can never be less than h, may be illustrated by resuscitating Maxwell's demon and permitting him to push a point about at will within any one of the rectangles. The movement of the point, that is, the corresponding changes of position and momentum, will not be detected, for they do not correspond to any detectable change in the world of sense.

Unfortunately the word "indeterminism," which has other connotations, has become associated with the statement of the principle. Many of us remember Clerk Maxwell's immortal account of the proceedings of our section at the Belfast meeting sixty-two years ago, when Mr. Herbert Spencer regretted "that so many members of the Section were in the habit of em-

ploying the word Force in a sense too limited and definite to be of any use in a complete theory of evolution. He had himself always been careful to preserve that largeness of meaning which was too often lost sight of in elementary works. This was best done by using the word sometimes in one sense and sometimes in another, and in this way he trusted he had made the word occupy a sufficiently large field of thought."

Is it heresy to suggest that some of us who have sung Canticles in praise of indeterminism and the disappearance of causality have given a similar generousness of meaning to these words?

Similar considerations apply to the term *observable*, which has suffered a sea-change in transference from its ordinary usage in the realms of perception. There is quite as much complicated physical theory lying between the perceptually observable marks on a photographic plate and the inferred frequencies, as there is between similar perceptual observables and the non-observable electron orbit or state which was inferred in order to subsume the perceptual facts. A similar generosity of treatment is accorded to the term *observe* when it is applied to the conceptual experiment for the determination of the position of a particle such as an electron.

Which brings us round to the starting-point of this discourse. Many of us who desire to proceed with our measurements untrammelled by these philosophic doubts have asked if there is not some canon by which the plain man could test his everyday beliefs. I suggest that a starting-point at least to this end is provided by a study of Karl Pearson's work, and that, with certain reservations and additions to the method discussed in the "Grammar of Science," we may develop a canon which will serve as a guide through the jungle of additional perceptual facts which the physical science of the twentieth century has added to that of its predecessors.[3]

Those who discuss the doctrine of causality do so with little reference to the attitude taken by the philosophers, and it may not be without interest—it certainly has some bearing on present-day thought—to consider the development of the notion of cause since the time of Newton. The views of Locke, Newton's elder contemporary, are clear and simple. He remarks:

> Thus, finding that in that substance which we call *wax*, fluidity, which is a simple idea that was not in it before, is constantly produced by the application of a certain degree of heat, we call the simple idea of heat in relation to fluidity in wax the *cause* of it, and *fluidity* the effect. . . . So that whatever is considered by us to conduce or operate to the producing any particular simple idea, whether substance or mode, which did not before exist, hath thereby in our minds the relation of a cause and so is denominated by us.

Newton, dominated as he was by the principle of causality and ever searching for a clear physical picture of the results of his investigations, was capable of a philosophic breadth of view which needs surprisingly little modification to-day. He makes, for example, a physical picture of matter as formed in "solid, massy, hard, impenetrable, moveable particles," and assumes that they have not only a *vis inertiae*, but are moved by certain active principles, such as gravity. These principles are to be considered

> not as occult qualities . . but as general Laws of Nature . . . their Truth appearing to us by Phænomena. . . . To tell us that every Species of Things is endowed with an occult specifick Quality by which it acts and produces manifest effects, is to tell us nothing; but to derive two or three Principles of Motion from Phænomena and afterwards to tell us how the Properties and Actions of all corporeal Things follow from these manifest Principles would be a very great step in Philosophy, though the Causes of those Principles were not yet discovered; and therefore I scruple not to propose the Principles of Motion above mentioned, they being of very general extent, and leave their Causes to be found out.

Evidently Newton takes the view that we have made an important step forward when we have subsumed a number of perceptual facts under a general formula.

It is to Hume, though he may owe something to Glanvil and other predecessors, that we are indebted for a clearly ordered statement of the experientialist doctrine of causation. The generalization, for example, that the earth attracts a stone is explained as a generalization from thousands of observations.

> Adam . . . could not have inferred from the fluidity and transparency of water that it would suffocate him, or from the light and warmth of fire that it would consume him. No object ever discovers by the qualities which appear to the senses, either the causes which produced it or the effects which will arise from it; nor can our reason, unassisted by experience, ever draw any inference concerning real existence and matter of fact.

Mill further developed the experientialist doctrine in the statement that the law of causation "is but the familiar truth that invariability of succession is found by observation to obtain between every fact in nature and some other fact which has preceded it, independently of all considerations respecting the ultimate mode of production of phenomena, and of every other question regarding the nature of things in themselves." To the doctrine of succession in this simple form the

[3] In what follows I have drawn on the material of an article which I wrote some four years ago (*Nature*, vol. 45, 1932, p. 130). See also Broad, "Perception, Physics and Reality."

objection has been urged that day may be regarded as the cause of night and conversely. Mill meets this objection by pointing out that invariable sequence does not necessarily involve causation. To involve causation the sequence must not only be invariable but *unconditional*. The day-night sequence is conditional by the sun and so does not conform to this test. "We may define, therefore, the cause of a phenomenon to be the antecedent, or the concurrence of antecedents, on which it is invariably and unconditionally consequent."

It is difficult to sum up Pearson's attitude to the problem of causality and to the general problem in a few sentences. Perhaps Kirchhoff's dictum concerning mechanics—"Die Mechanik ist die Wissenschaft von der Bewegung; als ihre Aufgabe bezeichnen wir: die in der Natur vor sich gehenden Bewegung *vollständig* und *ouf die einfachste Weise* zu beschrieben," touches very nearly the root of the matter.

We live, in fact, amid a mass of perceptions; and it is the business of physical science to correlate, in as simple a fashion as may be, a certain section of these facts. To this end the physicist devises a *conceptual* world of atoms and molecules, from which he builds up a system—a world-picture—of molar masses whose motions correspond to the routine of our sense impressions. Given a frame of reference, we can formulate laws of motion for two isolated particles in a conceptual world which may be summed up in the statement that whatever be the positions and velocities of the particles the ratio of their accelerations is always constant; this ratio is defined as the inverse mass-ratio of the particles; and in virtue of this we have the relation that—

$$\text{Mass of } A \times \text{acceleration of } A = \text{Mass of } B \times \text{acceleration of } B.$$

We give the name *force* to this product, and hence obtain the law that action and reaction are equal and opposite. On the basis of such definitions we can build up a structure of bodies in the conceptual world the motions of which, predictable under the descriptive laws formulated, will agree with the routine of our world of sense perceptions. We have in fact *explained* certain phenomena.

There is, of course, no logical reason why, in this description, we should stop short at the second derivative—acceleration—or go forward to it for that matter. We are concerned to find the simplest and most consistent explanation, and this procedure provides it. Indeed something of esthetics may also influence our choice.

The atom, whatever its complexity, whether the concept remains sharp as that of a billiard ball or a miniature solar system, or whether its outlines disappear in a probability-smear, remains a *concept* outside the realm of perceptual happenings which it is the business of the concept to correlate. It may or may not emerge into the perceptual world; unless and until it does discussion of its reality is beside the mark.

Planck, defining the causal condition in the statement that an event is causally conditioned if it can be predicted with certainty, goes on to remark that the possibility of making a correct prediction has not to be interpreted as anything more than a criterion for a causal correction, but not that the two mean one and the same thing. Day is not the cause of night, although we may be able to predict the advent of night in the day-time. Day is therefore a causally conditioned event.[4]

Taking the definition as it stands, we find that in the realm of quantitative physical events we can not, purely as a matter of measurement, predict *accurately* in advance any one physical event—this, without introducing quantum considerations. Professor Planck escapes from the indeterminist position by transferring the definition to a conceptual world in which exact measurements may be made and events correctly predicted. He assumes, in fact, in its broad outlines, the thesis of the "Grammar of Science." He thus retains the principle of causality, as defined above, in the happenings of the conceptual world, remarking that the relation between events in the perceptual and conceptual worlds is subject to a slight inaccuracy.

The introduction of Heisenberg's uncertainty principle necessitates a corresponding process in dealing with perceptual problems from the point of view of quantum physics. A conceptual world of quantum physics is framed in which a strict determinism reigns. True, the world has not so many points of resemblance to the perceptual world as had the older schemes—billiard-ball and solar-system atoms have disappeared, and the wave-function, which does not refer to ordinary space, is not so easily interpreted in terms of the world of sense. But the philosophical problem of the transfer is the same.

Whatever the form of the picture the hard-pressed physicist of to-day remains on firm ground if he refuses to confuse the concept—the world-picture—with the percept; if, making this distinction, he studies the question of the reality underlying phenomena as philosopher rather than as physicist; if he is as ready to discard outworn models as ever Maxwell was.

There is no finality in these matters, and solutions of these difficulties are solutions for a day; but it is interesting and heartening to know that Planck, the

[4] This definition should be carefully examined in the light of the argument of Hume ("Enquiry concerning Human Understanding," Section VII) and of Mill ("Logic," Book III, Chap. V).

initiator of the movement which has revolutionized physical thought, has, a generation later, pointed a way to a resolution of the fundamental doubts and difficulties which his genius has raised.

It must not be assumed that the discussion of uncertainty has passed beyond the region of fundamental criticism. In two recent papers in the *Philosophical Magazine*, Dr. Japolsky has developed a theory of elementary particles—electrons, protons, positrons, and so forth—which are considered as systems of Maxwellian electromagnetic waves. On this basis, using classical electrodynamics, he develops the usual quantum and relativity relations, including the de Broglie equation. The interaction of the particles follows the inverse square law (breaking down at small distances), and demands a mass-ratio between proton and electron which happens to be that deduced from experiment.

It is impossible to conclude a sketch of the trend of modern physics without touching upon the remarkable advances made in large-scale and applied physics; equally impossible is it to do more than mention a selection from such topics. The flotation process for the separation of minerals may be instanced as one, now of large-scale importance, which depends on a knowledge of physical quantities of very academic interest. In the practice of this process the powdered ore is churned in water which contains some substance capable of producing a stable froth. The mineral which it is desired to concentrate must cling to the surface and so remain in the froth, the gangue sinking to the bottom, and a reagent must be added whose action will ensure this. Obviously some very nice physical and physico-chemical problems are involved. In particular, a knowledge of contact-angles—a rather neglected subject—is of great importance, and during the last year or two much attention has been given to the measurement of contact-angles and to the application of the results of flotation processes. Indeed, a knowledge of surface-constants has many applications to industrial and to purely scientific problems, and it may not be out of place to draw attention to the curious shape of the curves showing the march of surface tension with temperature for certain crystalline liquids.

A most interesting application of classical atomic physics has recently been made in certain extensions of the theory of the Brownian movement. Measurements have been made of the Brownian movement of delicately suspended balances, movements due, of course, not to mass-motion of air or draughts but to irregular molecular bombardment, and a remarkably good value of Avogadro's number results from a determination of the amplitudes of such movements. Obviously if instruments become so delicate that their Brownian motion is appreciable, it becomes possible that Brownian motion may set a limit to the use of the instrument; this question has recently received consideration.

Electron diffraction has been applied with success to problems in technical physics. The very small penetration of even the swiftest electrons employed makes them peculiarly suitable for the study of surface structure, and the method has been used to attack such problems as the poisoning of oxide-coated filaments, and the study of lubrication.

Of the remarkable progress made in low-temperature research, we shall hear during the meeting of the section. One other matter may be mentioned in passing—the development of precision methods in calorimetry which may make it possible to study accurately the temperature-variation of the specific heats of liquids (deuterium oxide, for example) available only in small quantities.

Of recent years our association has concerned itself more and more with a study of the repercussions of the advancement of science on the fabric of our society. Never in the history of mankind have more powerful weapons for good and for evil been placed in the hands of the community as a direct result of the growth of scientific knowledge; and never has it been more necessary for the scientist to develop some awareness of the effects of his activities on the well-being of that community of which he himself is a responsible member.

We are most of us ready enough to discuss the "Impact of Science on Society," so long as we restrict ourselves to an enumeration of the benefits which science has bestowed upon mankind; and on occasion we may make a rather snobbish distinction between cultural and vocational values. But we have to remember actively that there are dysgenic applications of scientific knowledge, and if the scientist claims, as he rightly does, that place in the counsels of the nation which the importance of his work warrants, he must cease his worship of what Professor Hogben calls the "Idol of Purity," must be prepared to discuss all the social implications of his work and to educate himself, as well as his less fortunate brethren trained in the humanity schools, in a knowledge of these implications.

Our association is peculiarly fitted to develop and discuss such knowledge; in our own section we have made a beginning, but we have as yet touched on but few of these interactions. Our steps are naturally at first a little halting, but with increasing knowledge there will come, I trust, an increased power in elucidating those complex and difficult social problems which the astonishing developments of the last generation have forced on the civilized world.

TEACHING CHEMISTRY FOR ITS CULTURAL AND TRAINING VALUES[1]

By Professor J. H. SIMONS
PENNSYLVANIA STATE COLLEGE

TRAINING the intellect and the development of culture are two of the most valuable assets that can be obtained from any educational effort. That the subject of chemistry is an exceptionally fine medium for both of these has been emphasized in our symposium of last year. It is my purpose to attempt to discuss the teaching of the subject of these particular values. They are, without question, of tremendous importance, irrespective of the vocation the student eventually enters or the particular educational level under discussion. I am attempting to think of the subject of chemistry for its general educational values and not as a professional study for the training of chemists.

As both culture and a trained intellect may be understood in a variety of ways, it seems necessary to define these terms for the purpose of the discussion.

By intelligence I refer to those inherent qualities of mind that are used in thinking, and by thinking I imply clear, precise and logical reasoning. This involves a keenness of observation, which is accompanied by the power of concentration and an accuracy of memory, and also an orderly mind, which permits a clearness of thought and a fine differentiation of ideas. Judgment or the careful evaluating of facts and ideas is also implied. As analytical reasoning consists of keenness of observation, concentration on the subject at hand, a careful selection of pertinent data in an orderly arrangement and then a logical treatment toward a conclusion, the trained intellect must necessarily be skilled in logical thought processes and the ability to correlate facts and ideas.

That the subject of chemistry offers exceptional opportunities for intelligence training along these lines has been discussed somewhat at length in our symposium of last year. That it can be so taught is the burden of our present discussion.

Culture on the highest plane implies refinement and an ability to live at ease and understanding in the most enlightened and cultivated personal surroundings. With these go a familiarity and appreciation of the material environment as well as the human one. Among the usual connotations of the word are good taste and a broad general knowledge.

In a past age, when man had much fewer material comforts and the goal of education was to produce a knowing rather than a thinking intelligent man, culture included and required a knowledge of the classics. To-day we appreciate that the chief goal of education is to train the intellect, and our ideas of culture have suffered a corresponding change. We have compiled such a great volume of information that to know all or even to have a knowledge in all fields comparable with the great variety of people with which one comes in contact in the more enlightened society is quite impossible. A philosophical background with which to understand and appreciate knowledge and a trained mind to correlate and evaluate facts and ideas are much more important for true culture than great knowledge.

In our materialistic civilization of to-day with our innumerable gadgets and with constant reference in our books, magazines, newspapers and other publications to such things as Cellophane, hormones, ethyl gasolene, vitamins, lethal gas, heavy water, etc., a cultural development requires a knowledge and appreciation of the material universe and the varieties and transformations of matter. This, of course, is chemistry. Without this an individual can be at ease with neither his material nor human environment.

Culture also demands an esthetic appreciation of the works of man as well as the beauties of nature. It is the esthetic values of chemistry that are frequently not understood. To appreciate the works of man in this age a knowledge of materials is very important. But much more important than the mere knowledge is the understanding of the basic nature of substance. This is chemistry in the true sense. How is it possible for one to have a broad and deep esthetic appreciation of the works of man and nature without it?

Chemistry itself is one of the finest of man's creations. Our knowledge of the constitution of matter, the structure of its atoms and molecules, and the explanation of material phenomena on this basis is without doubt the most striking example of the power of the human mind. While the whole of chemistry is a structure at which to marvel, the individual pieces of creative activity which have gone to make the whole are gems of beauty and esthetic delight.

If one should smile at the comparison of a research accomplishment with a fine work of art, let it be remembered that it requires a knowledge and understanding to have a cultivated esthetic appreciation of artistic creations. The same is true of the creative accomplishments in science, which in a certain sense

[1] Paper read at a joint session of the Section of Chemistry, American Association for the Advancement of Science, and of the Division of Chemical Education of the American Chemical Society, St. Louis, January 1, 1936.

are forms of art supreme. It is this esthetic urge and satisfaction which scientists feel in their work and which gives them their greatest reward.

It is recognized to-day that the development of an understanding and appreciation of art is of greater moment for general education than the attempt to force all students to become creators of art. The same is true of the sciences like chemistry. Let us reserve the training of the creative or professional aspects of it for those who demonstrate a marked inclination and ability for it.

Although associations on the highest cultural level are reserved for the few, an understanding of the material universe and a foundation in its chemical aspects are of perhaps even greater value for those who find themselves in more ordinary society. The subject offers considerable value in cultural improvement for them, as material considerations play a more prominent part in their lives.

Can chemistry be taught to those students not interested in a career in science in a manner that will develop the cultural aspects of the subject, produce an appreciation of it and at the same time act as a medium for training the intellect? I believe it can. For cultural purposes it is not sufficient to cite numerous facts, interesting or otherwise, and insist upon the student memorizing them, only to have them gladly forgotten at the first convenient moment after the examination. The theoretical aspects must be emphasized, the philosophy of the subject developed and the thought processes made clear. The subject can be rigorous and profound without being technical and involving great masses of facts to be memorized. In this way it is more truly interesting, for the student is most interested in material upon which he can apply his own thinking abilities. The subject thus taught for the greatest cultural development is at the same time the method of teaching for the best mental training. I also believe that the subject taught in this manner is the best method of use for those whose use of it will be professional. The technical aspects can and are given later.

The science of chemistry has greatly changed in the past fifteen or twenty years. From a more or less descriptive science it has developed into a precise and theoretical one. It is philosophical in its outlook and demands much more thought and reasoning than pure memory. It is to-day a much better medium for both cultural development and intelligence training than it was a decade ago. It not only embraces the old subject of natural philosophy, but it is also the basis upon which our modern material improvements are made. It is not only esthetic and philosophical but extremely practical and practicable. Surely an intelligent, cultured individual requires some knowledge of it, and as surely there is a way of teaching it which will develop intelligence and culture and at the same time be extremely interesting.

The major content of such a course must necessarily be the theoretical structure of the science. It must emphasize the hypotheses upon which the science is built, and many of these have now been so firmly established as to be regarded as truths. It must stress the thought processes involved in the correlation or explanation of phenomena. It must build the science not upon a chronological or historical basis but in a consistent logical fashion. Naturally its chief aim for the beginning student is to instil in him the concepts of the atom, molecule, ion and electron (not to mention the neutron, photon, etc., which have not yet been sufficiently investigated to be included in an elementary course). It should attempt to develop in him the ability to think in terms of these primary particles of matter and relate its macroscopic properties to them. At least an introduction to the elements with their relationships and those of the simpler molecules formed from them should also be given. It should include a consideration of the properties of matter in bulk and show the correlation of the physical properties of the different states of matter with their structure of the primary particles. In other words, it should attempt to rationalize matter in the minds of the students. Modern chemistry is taught in this manner.

Such a rationalization tends to make the individual more at home in his material environment and develops an understanding and appreciation of the substances of his civilization. It also gives the basis for the esthetic appreciation of material structures. This is true cultural development.

As more emphasis is placed upon the thought processes than upon the factual material, this is also the way of teaching the subject for its greatest training values. Mental development, that is, training the mind in logical thinking processes, should be the prime goal of education, irrespective of the level.

There must necessarily be given a certain amount of factual material upon which to build the thought structure and with which to illustrate the principles. This, however, should be drawn as far as possible from that mass of chemical facts that can be considered necessary for the cultured, educated person. He should know the chemical basis of ordinary and frequently used substances. Modern chemistry is, however, not taught by reciting to the student, either in the form of lecture or text, a mass of facts, irrespective of how essentially interesting and amusing; and then requiring him to parrot these back in the form of recitation or examination. This might be the easiest method for the teacher, but it surely is not teaching the science of chemistry. I understand that this has been done in some so-called "cultural courses," but

emphatically it is neither cultural nor chemistry. Unless the subject is somewhat profound and rigorous it can be neither.

A certain amount of problem work is necessary in chemistry in all educational levels to develop the quantitative and exact side of the subject, but for the best teaching this is not of the nature where the student substitutes numerical data in some given formula and obtains an answer without any thinking processes involved. Mathematics is used in the science as the language of logic but not as a substitute for it. The more problems used of the thought-provoking nature the better the results of the teaching.

It is my opinion that certain factual material can be left out of the general courses, or at least given but little emphasis. These include the history of the science, biographies of famous chemists and descriptions of industrial processes. These may be brought in by the teacher on occasion to illustrate some point or enliven the subject, but surely the student should not be held for them. They are of unquestionable value and interest in themselves, but there is not sufficient time to really develop the subject adequately and deal with them also. For the specialist they are of greater interest but should be given some time late in their training. For cultural and training values they are of much less importance than the science itself. They are sometimes included in courses for general students for the purpose of exciting interest. I question the value of this, for the subject is of greater interest without them. The student is apt to look upon the history as just more names and dates to be memorized and upon biographies as the lives and works of some old fogies. The industrial processes given in some texts are unquestionably out of date and frequently only represent more memory drudgery to the students. When those things are brought in informally by the teacher from his background, it enlivens the subject much more than when they appear in the text.

Obviously the teacher at any educational level must have a much greater background than the subject at that level. To teach modern chemistry a philosophical rather than factual minded individual is required. To teach it for its cultural values requires a person with sufficient knowledge of the subject to have a keen esthetic appreciation of it. To use it for its training value demands an active thinking individual. As the subject contacts so many of our other fields of knowledge, a teacher with a broad knowledge can make the subject a better medium for cultural development than one whose background is more limited.

Our best teaching is done in the laboratory, for here the student and teacher come in intimate contact; and the student is kept actively at work mentally and physically under the guidance of the teacher. It is here where we accomplish what some of our greater universities are attempting in their tutorial systems. For training purposes it gives us our best opportunities. As it develops a realistic familiarity with substances by intimate contact, it produces a sounder appreciation of them than lecture or text-book material. It is this appreciation which is of such great cultural value. In modern chemistry courses the laboratory is not conducted by giving the student recipes for his work, which he follows blindly. Selected problems are given, which require the student to think about what he is doing and how he is doing it. Frequently, he is guided by means of a set of questions. What could be a more ideal way of teaching!

In some circles the opinion is or was common that the use of the hands is unrefined and menial. This is quite opposite from the truth. The anatomical structure of man's hand and arm, which make them such a uniquely useful organ, is quite probably the basic cause for the development of the brain. Man's hand is just as superior in flexibility to analogous organs of animals as is his brain. In the history of civilization the invention of new tools has either preceded or paralleled new ideas or philosophies. Performing intellectual tasks through the use of manual processes is one of the best means for mental training. It makes the material more intimate and realistic. For this reason also the chemical laboratory, with instruction given from a modern point of view and designed particularly for training and development rather than for the accumulation of facts or performing routine, is an excellent means for the achievement of cultural and training educational values.

In order to use the subject educationally to its best advantage it is not necessary that all the latest facts and ideas in the science be incorporated in the elementary courses. It is much more important to weed out unessential facts, ideas and points of view that have changed with the advance of the science. As the entire outlook has changed in the past decade, it is important that this change be made in our teaching. This requires that we treat the subject on a logical and philosophical basis rather than a factual or descriptive one. As it is on this basis that it is the better training and cultural medium, it is especially important that it be treated in this manner for the non-professional students and on the more elementary levels. It is my opinion that students in general have a keener interest and appreciation for the philosophical aspects of school work than most teachers recognize. Taking advantage of this improves our educational effort.

As chemistry is growing and changing at a very rapid rate, it is difficult to keep the school courses up to date. This fact, however, enables the teacher to handle the subject as a living thing. He can disagree

with the text and show how the subject has advanced since the text was written. This disagreement is excellent for the mental development of the student. It creates a more critical attitude and helps destroy the feeling that the written word is absolute truth. As an example, I have a habit of demanding that definitions be made at the time required and not committed to memory with the expectation that they are fixed and inflexible. It is by changing our definitions that advances are made, and I hope to impress this upon the students. In the same way I require that mathematical expressions be derived for the particular purpose at hand and not memorized to use as a mental crutch for all similar problems. I expect the student to understand the ideas underlying the formula so that it can be derived easily at any time rather than committing to memory a group of symbols.

As a cultural subject of the first rank and as a medium for mental development, chemistry has exceptional educational merit. The modern philosophical point of view has made it possible to utilize it much more fully for these purposes. For the most truly cultural use the subject must be made rigorous and sound rather than factual. The laboratory gives the teacher an excellent opportunity to use it to its fullest extent. Because it is so widely taught and because it is of such potential value, we should insist that its teachers be competent and above all be adequately trained in the subject and have its modern point of view.

OBITUARY

EDWIN OAKES JORDAN

EDWIN OAKES JORDAN was born in Thomaston, Maine, on July 28, 1866, and died on September 2, 1936. He took his bachelor's degree in science at the Massachusetts Institute of Technology in 1888 and the degree of doctor of philosophy at Clark University in 1892 where he had been fellow in morphology for two years. Caught in the migration from Clark University to the newly founded University of Chicago, he came to the latter in the fall of 1892 as associate in anatomy. In 1895, however, he was made assistant professor in bacteriology—one of the earliest academic appointments in this country in general bacteriology—and thus began a steady advance (he was given the rank of professor in 1907) and expansion leading to the organization in 1914 of the department of hygiene and bacteriology of which he was the head until his retirement in 1933. The previous year the university awarded him the Andrew MacLeish distinguished service professorship.

He was married in 1893 to Elsie Fay Pratt, who survives him. There are three children: Henry Donaldson, professor of history in Clark University; Edwin Pratt, physician and clinical instructor in Rush Medical College of the University of Chicago; and Lucia Elizabeth, physician and married to Dr. Charles L. Dunham, assistant in medicine at the University of Chicago.

Dr. Jordan soon built up a well-organized center in bacteriology. The number of students, advanced as well as beginners, grew large and many are the bacteriologists now scattered far and wide in various lines of work who received instruction from him and inspiration from his quiet enthusiasm for the advancement of bacteriology. He was a clear, kindly and cultured teacher, placing the emphasis on fundamental principles. He was a master of exact statement. In 1899 he published a translation of Hueppe's "Principles of Bacteriology," but his main contribution in that line is his "General Bacteriology," a leading textbook from its first publication in 1908 and now in its eleventh revised edition. Himself an active investigator from the start, his laboratory was always a focus of significant research on bacteriologic and sanitary problems. He was ever on the lookout for able students who might be trained in research. As the general interest in public health developed his influence increased in widening circles and with it the recognition of the scope and importance of his work.

He took active part in the work of many scientific associations. He was a founder and president of the Society of American Bacteriologists, which elected him to honorary membership on his retirement. In the American Public Health Association he was an influential member of a committee on methods of water analysis, the report of which, a standard of its kind, has passed through several editions. He was president of the Chicago Pathological Society in 1906 and of the Institute of Medicine in 1932. He was for a time a member of the medical fellowship board of the National Research Council and served for several years on the International Health Board of the Rockefeller Foundation and later as a member of the board of scientific directors of its International Health Division. He also served on the council of foods of the American Medical Association. The health commissioner of Chicago leaned heavily on him for guidance, and when the present board of health was organized he was one of its members.

A paragraph may be devoted to his relations to the John McCormick Institute for Infectious Diseases, of which he was a trustee. He was joint editor of the *Journal of Infectious Diseases,* published by the institute, from the issue of the first number in 1904.

To his influence and active concern in its conduct, especially in the early years, the journal owes more than to any other factor. Soon after the formation of the institute in 1902 it appeared that the cost to the public of diphtheria antitoxin was excessive. By way of practical demonstration the institute, under Dr. Jordan's guidance, organized a serum division for the manufacture of diphtheria antitoxin and sale at cost. Dr. Jordan had complete charge of this division until it was discontinued as no longer needed. He edited the *Journal of Preventive Medicine,* also published by the institute, until it was taken over by the *American Journal of Hygiene,* when he became co-editor of the issues relating to epidemiology.

At the request of the American Medical Association through its committee on scientific research he wrote a masterly review and digest of the literature on epidemic influenza,[1] with special reference to its causation, which crystallized the existing knowledge and stands as a guiding landmark in the literature of the disease.

It was in zoology under Charles O. Whitman that Dr. Jordan studied for his doctor's degree. His thesis was on the water newt, Diemyctylus. This training did much to give him the broad biological background which is characteristic of his later work. The awakening of his interest in bacteriology and sanitary science took place earlier, however, and was ascribed by him to the influence of one of his instructors at the Massachusetts Institute, namely, Wm. T. Sedgwick (1855–1921), the great pioneer epidemiologist and sanitarian. In 1888 Sedgwick was appointed biologist to the Massachusetts State Board of Health, and under him as chief assistant Dr. Jordan carried on investigation[2] of the purification of water and sewerage until he took up the fellowship in Clark University in 1890. The tracing by Sedgwick of the typhoid epidemic in the Merrimac Valley to the water of a polluted brook surely made a deep impression on his young assistant. It is noteworthy that Dr. Jordan was one of the authors of a biography of Sedgwick[3] and that in 1934 the American Public Health Association awarded him the Sedgwick Memorial Medal for "distinguished service in public health." Here it may be mentioned also that the University of Cincinnati conferred on him the honorary degree of doctor of science and that in the spring of 1936 he was elected a member of the National Academy of Sciences.

No attempt will be made now to analyze in detail Dr. Jordan's investigations, which not infrequently were carried out in conjunction with pupils or assistants. These investigations may be divided roughly into three main groups—those dealing with problems in pure bacteriology, those dealing with problems in medical bacteriology and those dealing with problems relating to public health, sanitation and epidemiology. Of the first group may be mentioned studies on bacterial metabolism, pigment production, motility, variation; studies on the biology of the influenza bacillus; studies on intestinal bacteria; and studies over many years on the paratyphoid-enteritidis group to the knowledge of which he added much. In the second group are his studies on bacterial food poisoning and food-borne infection begun systematically about 1915.[4] In 1930 he made the discovery that certain common forms of food poisoning with acute gastro-intestinal symptoms may be caused by toxic products elaborated in foods by contaminating staphylococci. He was engaged to the last in actively investigating the production by bacteria of enterotoxic substances. The third group of investigations will be summarized in their relations to practical applications. Dr. Jordan did not recognize any well-defined demarkation between pure and applied science; he found ample occasions in the applied science in his field to carry on work of fundamental scientific significance. He had a keen sense of social responsibility and welcomed opportunities for practical service in the promotion of public health. The full list of his varied activities in that direction would be long and impressive. He was a frequent and highly valued consultant in regard to problems of water supplies and epidemic diseases, at first especially typhoid fever. In connection with the controversy about the Chicago drainage channel, in which he was adviser to the Sanitary District of Chicago, he took a leading part in experimental and other work of fundamental importance on the self-purification of streams. That was in the years 1899 to 1903. From then on he followed closely the effects of preventive measures on the incidence of typhoid fever and other diseases, including diphtheria. His interpretations of the statistics stimulated improvements in city water supplies and thus hastened the effective prevention of water-borne typhoid. He published the records of studies of many typhoid outbreaks. He was influential also by investigation and discussion in the development of a sound basis for the pasteurization of milk for general use. Unobtrusive but patient and tactful, he handled practical problems with singular effectiveness by reason of a firm grasp of basic principles coupled with good judgment.

Finally, it should be said that all Dr. Jordan's writ-

[1] "Epidemic Influenza; a Survey," pp. 599. Chicago: 1927, American Medical Association.

[2] Special Report, Massachusetts State Board of Health, Part 2, 1890.

[3] E. O. Jordan, G. C. Whipple and C.-E. A. Winslow: "A Pioneer in Public Health, William Thompson Sedgwick," 1924. Yale University Press, New Haven.

[4] "Food Poisoning and Food-Borne Infection." 1917. Second edition, 1931. University of Chicago Press.

ings are of a remarkably high order of literary culture and style, general scholarship and soundness. The results of his work stand well the tests of time. He was eminent in teaching, in research and in the application of bacteriologic science to public health.

LUDVIG HEKTOEN

RECENT DEATHS

DR. WILLIAM BUCHANAN WHERRY, professor of bacteriology and hygiene at the University of Cincinnati, died on November 1, in his sixty-first year.

COMMANDER JOHN THOMAS WATKINS, who retired six years ago as chief of the Magnetic Division of the U. S. Coast and Geodetic Survey, died on October 29 at the age of sixty-five years.

JAMES A. HALL, professor of mechanical engineering at Brown University, died on October 29 at the age of forty-eight years.

ALEXANDER LARMOR, formerly McCrea professor of natural philosophy at Magee University College, Londonderry, Ireland, now affiliated with the University of Dublin, died on October 12. He was a brother of Sir Joseph Larmor, of the University of Cambridge.

SCIENTIFIC EVENTS

MAPPING OF AREAS IN NORTHWESTERN QUEBEC

WORKING mainly in areas that are being actively prospected and developed, field parties of the Canadian Geological Survey, Department of Mines, Ottawa, are mapping seven sections of northwestern Quebec this year. Geological investigations are under way in the Opemiska, Waswanipi, Malartic, Noranda and Amos areas, and in the Mistawak area to the north of the Normetal (Abana) property, with topographical projects in the Noranda and the Mistawak areas.

Investigations by G. W. H. Norman in the Opemiska area will furnish information for a detailed geological map. Operations at the Ventures controlled Opemiska property are the center of interest in this increasingly active mining field. Prospecting and development work is also proceeding on deposits in the vicinities of David, Simon, Gwillim and Father Lakes. In the course of his work Dr. Norman will visit recent mineral discoveries in the Opawica-Chibougamau area.

The eastern and western portions of the Waswanipi area are being mapped by B. C. Freeman and J. C. Sproule on a four-mile-to-the-inch scale. The work is intended to meet the immediate needs of prospectors.

H. C. Gunning and J. W. Ambrose are making detailed geological investigations in Malartic and Fourniere townships. During 1934 and 1935 the geology and mineral deposits along the Cadillac gold belt were mapped in detail, and the more important economic results were published early in 1936. Last year this belt was traced southeastwards to within three miles of the Canadian Malartic property, and attention was thus directed to several miles of potentially valuable territory. This year's work is intended to establish the relationship existing between the two principal gold camps in the area, and should further assist the development of intervening and adjoining territory.

An area to the east of Amos is being mapped by L. J. Weeks, in a continuation of the systematic geological mapping of this section of western Quebec as an aid to prospecting.

G. F. Flaherty commenced the detailed mapping this year of the Mistawak area lying between the Ontario boundary and the Waswanipi area. Bands of tuffs and sediments similar in character to those in Desmeloizes township to the south are being delimited, and prospects in the area are being examined.

M. E. Wilson is completing a geological study of the Noranda mine. This work is part of a study of various deposits in the area, and is designed to determine their modes of occurrence as an aid to future development.

A portion of the Noranda area, and the strip of country between Noranda and Malartic township are being mapped topographically by J. W. Spence as a control basis for later geological investigations. In the Mistawak area H. N. Spence is mapping a 6,000-square mile territory lying mainly to the north of the Transcontinental Railway. This work will provide maps for prospectors and settlers in the area.

ENDORSEMENT OF THE WORK OF THE U. S. WEATHER BUREAU BY CIVIL ENGINEERS

AN endorsement of the program and work of the U. S. Weather Bureau and a resolution urging public support for its efforts to enlarge and improve its service have been passed by the Board of Direction of the American Society of Civil Engineers. Calling for an increase in appropriations for the work of the Weather Bureau and naming six specific activities in which it believes expansion in personnel and equipment are needed, the board has issued the following statement:

> Contacts of the society's Committee on Meteorological Data, with the program and work of the U. S. Weather Bureau, have convinced the committee that the bureau should receive public support in its efforts to enlarge and improve its service. With this in mind, the Board of Direction of the American Society of Civil Engineers, at its fall meeting, voiced its approval of this government activity by adopting the following resolution:

WHEREAS, More accurate and complete meteorological data are essential to many branches of human endeavor including navigation, agriculture, aviation and engineering; and

WHEREAS, The Special Committee on Meteorological Data of the American Society of Civil Engineers, the Water Resources Committee of the National Resources Committee and the Advisory Committee to the Secretary of Agriculture on the Weather Bureau, have all urged expansion and improvement of the service furnished by that bureau, which will call for an increase for appropriations for the bureau, now deemed inadequate even for the present service; therefore, be it

Resolved by the Board of Direction of the American Society of Civil Engineers that it endorses improvements in the service of the Weather Bureau, and the provision of an adequate increase in appropriation therefor, especially along the following lines:

(a) Stimulation of the service by adding qualified new men, by additional training of selected men now in the present organization, by further personal contact between field and office officials, and by regular inspections of both first-order and voluntary stations.
(b) Research.
(c) Extension of upper-air observations to attain, if possible, more exact and longer range forecasting.
(d) Increased number of observation stations, especially in the higher mountain areas, and reports from more ships at sea.
(e) Snow surveys and evaporation observations from water, snow and soils.
(f) The complete adoption and use of the International Figure Code.

Dr. Daniel W. Mead, professor emeritus of hydraulic and sanitary engineering, University of Wisconsin, is president of the society and chairman of the board. George T. Seabury, New York, is secretary.

THE TWELFTH NATIONAL EXPOSITION OF POWER AND MECHANICAL ENGINEERING

THE twelfth National Exposition of Power and Mechanical Engineering will be held at the Grand Central Palace, New York City, during the week of November 30. Three floors will be occupied and admission will be by invitation or by registration only. Operating exhibits will be emphasized and the equipment on display will range from power-producing equipment, factory machinery and industrial equipment to materials of construction and plant accessories.

The exhibits of equipment and products have been designed to meet current needs. Machinery will be in operation. All the effective principles of modern display will be utilized to show products so that they may be easily inspected and so that attention will be drawn to their new and important features. Competent men from technical staffs will answer questions, demonstrate products and explain how principles may be applied to the specific problems of the inquirer. The comprehensive presentation, including the latest output of competitive manufacturers, will provide visiting executives and engineers with a sound basis for their comparison of relative advantages.

Exhibits will range from large, heavy equipment used in the generation of power to mechanical equipment for handling materials and tools. Classifications of equipment on display will include: fuels, combustion equipment; refractories, steam-generating equipment; steam distribution equipment; piping and fittings; prime movers, pumps and hydraulic equipment; electric generators and motors; electrical transmission, distribution, control; power transmission; control apparatus and precision instruments; power-driven machinery; tools and machine tools; material handling equipment; heating, ventilating, refrigeration, air conditioning; lubricants; operation and maintenance materials.

Machinery and operating plant equipment will constitute a major section of the exposition. Steam-generating equipment and accessories will as usual play a prominent part. Valves and controls of every type and the latest in pipe fittings in terms of their industrial applications will be displayed. Many exhibits will feature plant accessories. A complete line of pumping equipment will offer unusual features from the standpoint of operating efficiency. Innumerable exhibits will be devoted to the latest indicating, recording and controlling devices applicable to temperature, flow, pressure, level and time.

The American Society of Mechanical Engineers and the American Society of Refrigerating Engineers will hold meetings in New York during the week of the exposition.

THE PONTIFICAL ACADEMY OF SCIENCES

A NEW Pontifical Academy of Sciences was initiated by Pope Pius on October 30. It was announced that members had been selected solely for scientific achievement. It consists of seventy members as follows: Italy, 33; United States, 6; France, Germany and Belgium, 5 each; Holland, 4; Great Britain, 3; Austria, 2, and Czechoslovakia, Portugal, Argentina, Denmark, Norway, Poland and China, one each.

From the United States the following have been elected to membership: Alexis Carrel, professor of biology at the Rockefeller Institute, New York; George Birkhoff, professor of mathematics at Harvard University; Robert Andrews Millikan, director of the Norman Bridge Laboratory of Physics at the California Institute of Technology; Thomas Hunt Morgan, director of the Wm. G. Kerckhoff Laboratories of the Biological Sciences of the California Institute of Technology; George S. Sperti, biophysicist, formerly research professor at the University of

Cincinnati; Dr. Hugh S. Taylor, professor of chemistry, Princeton University.

Among the Italians elected are: Guglielmo Marconi; Umberto Nobile, aviator, and Aldo Castellani, known for his work in tropical medicine, and Senator Vito Volterra, formerly professor of physics and mechanics at the University of Rome.

The Pope has issued the following statement in regard to the organization of the academy:

Among the many blessings with which the divine goodness has rejoiced the years of our pontificate, we should like to enumerate those afforded by the spectacle of so many men who have dedicated themselves to study of experimental sciences and who have changed their attitude and intellectual cause as regard to religion.

Unfortunately it is true that in times not so long gone some learned men, for reasons other than love of truth, have abandoned as prodigal sons the paternal roof or the religion of their forefathers. Especially during the last century there were those who taught the false, rash argument that the findings of human science were in open contradiction to the teachings of divine revelation.

It is, however, a source of profound joy to our heart that in our day these prejudices are so evidently outmoded that there are few who really have studied the positive sciences and yet continue to sustain this error.

On the contrary, during our pontificate many scientists, among whom were men of the highest worth and standing, have come to Rome from distant lands in order to participate in scientific congresses and have come to our presence to express their devotion to us, or rather to that authority which lives forever in the apostolic see, even though exercised by an unworthy successor of St. Peter.

There were those who acted in their own names and the names of their colleagues who did not hesitate to say that true science leads and prepares the soul to faith—a confession which gave our heart profound happiness.

SCIENTIFIC NOTES AND NEWS

THE Nobel Prize for physiology and medicine has been awarded to Sir Henry Dale, director of the British National Institute of Medical Research, and to Professor Otto Loewi, professor of pharmacology at Graz, for their work on the part played by acetylcholine in innervation.

THE Hoover gold medal, "awarded by engineers to a fellow engineer for distinguished service," will be presented to Dr. Ambrose Swasey, chairman of the Board of Directors of the Warner and Swasey Company, Cleveland, Ohio, at the annual dinner of the American Society of Mechanical Engineers to be given in New York City on December 2.

THE William H. Nichols Medal of the New York Section of the American Chemical Society, founded in 1902 to "stimulate original research in chemistry," has been awarded for 1937 to Dean Frank C. Whitmore, of the School of Chemistry and Physics of the Pennsylvania State College, "for his studies in metallo-organic compounds, especially those of mercury, and in the field of aliphatic chemistry, particularly in molecular rearrangements."

AT the recent Cleveland meeting, the Samuel Wylie Miller Medal of the American Welding Society was presented to Metcalf Hobart, consulting engineer of the General Electric Company, Schenectady, N. Y., in recognition of his work as "a pioneer in the art of welding who has done outstanding service toward the development of welding into the most important and widely used tool of industry."

Nature reports that the Riberi Prize, founded by an Italian surgeon, for the best contribution to the progress of medicine within the last five years, has been awarded to Dr. Francesco Pentimalli, professor of general pathology at Florence, for his work on experimental tumors and cancer.

THE honorary degree of doctor of civil law was conferred on October 27 by the convocation of the University of Oxford on Dr. James Bryant Conant, president of Harvard University.

THE doctorate of laws of McGill University was conferred on October 23 on Nevil Norton Evans, who recently retired from the professorship of chemistry, and on Dr. Maude Abbott, formerly professor in the faculty of medicine.

FRANK MALCOLM FARMER, vice-president and chief engineer of the Electrical Testing Laboratories, New York City, has been elected chairman of the Engineering Foundation. Mr. Farmer succeeds H. P. Charlesworth, assistant chief engineer of the American Telephone and Telegraph Company.

A BANQUET in honor of Dr. Daniel Webster Mead, professor of hydraulics and sanitary engineering at the University of Illinois and president of the American Society of Civil Engineers, was given at New Orleans on October 24 by the Louisiana section of the society on the occasion of the meeting there of the American Public Health Association.

AT the Philadelphia meeting of the American College of Surgeons Dr. Frederic A. Besley, of Waukegan, Ill., was elected president. He will take office next year, succeeding Dr. Donald C. Balfour, of Rochester, Minn. Dr. Frank W. Lynch, San Francisco, was elected first vice-president, and Dr. Austin

B. Schinbein, West Vancouver, B. C., second vice-president.

SIR ALBERT CHARLES SEWARD, professor of botany, having retired from the mastership of Downing College, Cambridge, has been elected into an honorary fellowship.

DR. PAUL S. BURGESS, dean of the College of Agriculture of the University of Arizona, has been elected president of the university to succeed Dr. Homer LeRoy Shantz, who is now chief of the Division of Wildlife Management of the Forest Service. Dr. Burgess has been acting president of the university since the resignation of Dr. Shantz.

DR. ARTHUR W. EWELL, professor of physics at the Worcestor Polytechnic Institute, has been appointed head of the department of physics, succeeding Professor A. W. Duff, who has been appointed professor of physics emeritus.

DR. WILLARD BERRY, of the Ohio State University, has been appointed assistant professor and chairman of the department of geology at Duke University, Durham, N. C.

ALFRED R. MACORMAC, research assistant professor of chemistry at the University of North Carolina, has become associate professor of textile chemistry at the Alabama Polytechnic Institute.

CHARLES G. DUNCOMBE, instructor and assistant professor at the Ohio State University, has become professor and head of the department of chemical engineering at the University of Detroit. He succeeds Henry L. Coles, who was recently appointed head of the department of chemical engineering at the University of Colorado.

RECENT appointments in the department of chemistry of the Ohio State University are: Assistant professor, Laurence L. Quill, associate, University of Illinois; instructors, Dr. Alfred B. Garrett, assistant professor, Kent State University, Ohio; Dr. John P. Howe, fellow-elect, 1936–37 (resigned), of the National Research Council; Dr. Wm. McNevin, formerly instructor at Harvard University; Dr. Melvin S. Newman, Eli Lilly fellow, Harvard University, 1934–36, and Dr. Frank H. Verhoek, Rhodes scholar, Institute for Chemical Physics, Copenhagen.

DR. FERNANDO CALDERON Y ROCA, having reached the age of seventy years, has retired as dean of the College of Medicine of the University of the Philippines, director of the School of Hygiene and Public Health, head of the department of gynecology and director of the Philippine General Hospital.

DR. W. E. CASTLE, professor emeritus of Harvard University, has been appointed research consultant in mammalian genetics at Brown University. Upon Professor Castle's retirement from Harvard his stocks of rabbits, containing the less common and irreplaceable mutants, were transferred to Brown University, where they are being perpetuated and utilized in further research under the direction of Dr. P. B. Sawin, aided by a grant from the Rockefeller Foundation. Dr. Castle is now resident at Berkeley, California, where he is continuing his researches on rodent genetics.

DR. ARTHUR M. BANTA, professor of biology at Brown University, is spending a sabbatical year at the Station for Experimental Evolution, Cold Spring Harbor, as an associate of the Carnegie Institution. He is engaged in bringing up to date the manuscript work on his studies on the genetics and evolution of Cladocera.

DR. G. E. COGHILL announces that, although without official connection with any laboratory, he is continuing his research and hopes that those who have formerly sent him copies of their scientific papers will continue to do so. Until further notice his address will be Beaufort, N. C.

DR. ALICE BORING, a member of the faculty of the University of Peiping, is working in collaboration with Clifford H. Pope at the American Museum of Natural History on the life histories of amphibia.

DR. BENJAMIN FRANKLIN HOWELL, of Princeton University, has been appointed associate curator of geology at the Academy of Natural Sciences of Philadelphia. He will work at the academy during the coming year on a part-time basis, supervising the arrangement of a collection of 200,000 fossil specimens assembled during the past century.

DR. ISAIAH BOWMAN, president of the Johns Hopkins University, has been giving a series of Messenger lectures at Cornell University on "Geography and the Needs of the State."

DR. EUGENE M. LANDIS, of the Robinette Foundation at the University of Pennsylvania, will give the second Harvey Society Lecture at the New York Academy of Medicine on November 19, at 8:30 P. M. The subject of the lecture will be "The Passage of Fluid through the Capillary Wall."

DR. L. H. ADAMS, physical chemist at the Geophysical Laboratory of the Carnegie Institution of Washington, gave a public lecture at the institution on October 27, on "The Earth's Interior; Its Nature and Composition."

THE Lancaster Branch of the American Association for the Advancement of Science for the year 1936–37 opened with a lecture by Professor C. T. Brues, pro-

fessor of economic entomology at Harvard University and associate curator of insects at the Harvard Museum of Comparative Zoology. His subject was "The Animal Life of Hot Springs." Among those who are expected to speak during the year are: Austin H. Clark, U. S. National Museum, zoology; Dr. L. O. Grondahl, Union Switch and Signal Company, physics; Dr. H. B. Humphrey, U. S. Department of Agriculture, botany; Dr. Earl B. McKinley, George Washington University, bacteriology; Dr. C. E. Kenneth Mees, Eastman Kodak Company, photography; Lieut. Albert W. Stevens, U. S. Army, aeronautics, and Dr. James A. G. Rehn, Academy of Natural Sciences of Philadelphia, entomology.

E. R. SQUIBB AND SONS, of New York City, manufacturers of medical and chemical products, have established a fellowship at Harvard University for research in organic chemistry. The first award, of $2,000, has been made to William P. Campbell, of Hagerstown, Md., for research on phenanthrene with Professor Louis F. Fieser.

THE Committee on Scientific Research of the American Medical Association has made the following grants: to Dr. S. W. Ranson, of the Northwestern University Medical School, to aid research into the effect of fever-producing bacterial toxins on the temperature of animals whose heat-regulating mechanism has been destroyed by lesions of the hypothalamus; to Dr. Abraham White, instructor in physiological chemistry in the Yale School of Medicine, for aid in continuing investigations of the sulfur of proteins; to Dr. Roe E. Remington, of the Medical College of the State of South Carolina, for work on quantitative changes in the thyroids of rats fed iodine deficient diets, and to Professor Benjamin Harrow, of the College of the City of New York, for work on hormones in the urine.

THE following lectures were given during October in the twelfth series of free illustrated scientific lectures under the auspices of the California Academy of Sciences, San Francisco, on the general subject, "The Beauties of Nature": "Native and Introduced Trees of the Pacific Coast," by Dr. Howard E. McMinn, professor of botany at Mills College; "Plant Collecting on Palawan Island, Philippines," by Dr. Fred W. Foxworthy, formerly professor of dendrology, University of the Philippines, and later forest research officer of the Federated Malay States; "What State Parks Mean to California," by William E. Colby, chairman of the California State Division of Parks. The lectures were given in the auditorium made available through the cooperation of the Pacific Gas and Electric Company.

THE fall meeting of the Middle Atlantic Section of the Society for the Promotion of Engineering Education will be held at Columbia University in New York on December 5. Emphasis will be placed on the humanities content of engineering curricula. Guided visits will be made to points of interest on Morningside Heights, including Riverside Church, the university museums and collections and various buildings of the university. The afternoon meeting will be followed by special demonstrations in the engineering laboratories, including a demonstration by Professor E. H. Armstrong of his new system for radio broadcasting.

THE usual spring joint meeting of the Institute of Radio Engineers and the American Section of the International Scientific Radio Union will be held in Washington, D. C., the tentative date being April 30, 1937. This meeting is a feature of the week which attracts to Washington every year a large number of scientific men and scientific societies. Papers on the more fundamental and scientific aspects of radio will be presented. Titles and abstracts of papers offered for this program may be submitted to S. S. Kirby, technical secretary, American Section, International Scientific Radio Union, National Bureau of Standards, Washington, D. C., not later than February 15, 1937.

Nature reports that in view of the many requests that have been received from those who attended the conference on mechanization in agriculture held in Oxford last January, it has been decided to hold a second conference at Rhodes House, Oxford, on January 5 to 8, 1937. A detailed program will be sent on application to the Conference Secretary, Institute for Research in Agricultural Engineering, Parks Road, Oxford.

DR. HAROLD S. COLTON, director of the Museum of Northern Arizona at Flagstaff, writes that the museum has received and is now engaged in cataloguing the geological library of the late David White, paleobotanist of the National Museum. This library is composed of books, reprints, proceedings of societies, reports, bulletins and professional papers of the U. S. Geological Survey, Proceedings of the Smithsonian Institution and the National Museum, state geological surveys and other series, which number in all about 1,000 volumes and 2,000 reprints. Dr. Colton writes: "Besides this collection the museum has received 125 reprints on paleontology, a gift from Mrs. Rudolf Schmieder, of Philadelphia. The Museum Library has been strong on anthropology and Western Americana of the Southwest. These new collections give the library a very good start in geology. It is the only working library in these fields close to the Grand Canyon."

OREGON STATE COLLEGE has received the gift of a library on mining and geology, belonging to the late Hiram Dryer McCaskey, an authority on the

gold, silver and quicksilver resources of the United States and the mineral and geological characteristics of the Philippine Islands. Consisting of nearly 3,000 volumes and pamphlets, the library includes many out-of-print bulletins of the U. S. Geological Survey as well as the transactions of the American Institute of Mining Engineers since the beginning of the organization in 1871.

SUCCESSFUL use of radio communication service in fighting recent forest fires at Isle Royale, Mich., Great Smoky Mountains National Park and Glacier National Park is reported by the National Park Service. John D. Coffman, chief forester, advocates experiments in the use of high and ultra-high frequency radios and its adaptation to National Park Service needs. He states that in Isle Royale the National Park Service was completely dependent upon radio for communication. This was the case both between the island and the mainland, and between various base and side camps on the island where 1,600 men from the CCC camps were billeted for a month. Without radio there would have been no communication service. On September 1 there were eleven radio sets in operation on Isle Royale. Also in the fire suppression work carried on in Great Smoky Mountains National Park and in Glacier National Park, Mont., the radio played an important part.

DISCUSSION

A DOZEN MATHEMATICAL ERRORS IN WEBSTER'S DICTIONARY

TWENTY-FIVE years elapsed between the publication of Webster's "New International Dictionary" and the extensively revised second edition (1934), and it may be assumed that this second edition will be used in practically its present form for many years. It may therefore be of interest to mathematical students to note here a sufficient variety of definite errors which appear therein and relate to their subject to inspire the desirable caution which is too often lacking in the use of standard works of reference, especially on the part of the younger students. The suggested corrections may enable some to improve their own copies of this standard book by adding appropriate notes. A few other modifications relating to this dictionary were suggested by the present writer in SCIENCE, 81: 513, 1935.

Under the term "spherical excess" it is stated that "its product by twice the square of the radius of the sphere on which the triangle is drawn is equal to the area of the triangle." As the correct rule for finding the area of a spherical triangle appears in many of our school text-books it is easy to verify that the word "twice" should not appear in this quotation. Under the term "primitive group" there appears the following definition: "A transitive group of substitutions on n letters such that all the substitutions of the group which omit a given letter form a group involving all the other letters." This condition is obviously not satisfied by the regular primitive groups of prime degrees and there are also transitive groups which satisfy this condition but are not primitive. As an example of the latter we cite the group of degree 6 and of order 72. The given condition is therefore neither necessary nor sufficient.

Under the term "dicyclic group" appears the following supposed definition: "A group generated by two elements a and b, in such a manner that every element is of the form a^x or ba^x, the element a satisfying the equation $a^{2m} = 1$, and the element b having its square $= a^m$, where m is an integer." While every dicyclic group satisfies this definition there are many other groups which also satisfy it. A necessary and sufficient condition that a group satisfies it is that it involves a cyclic subgroup of index 2 and at least one element of order 4 which does not appear therein. In particular every abelian group whose independent generators are of orders 2 and $2m$, where m is even, satisfies the given definition, but none of these groups is dicyclic according to the usual definition of this term. Under the term "dihedral group" there appears an illustrative example which implies that the dihedral group of order 8 is known as the axial group instead of the octic group.

Under the term "binomial theorem" there appears the following sentence: "The theorem propounded by Sir Isaac Newton by means of which a binomial may be raised to any power without performing the multiplication." The implication is that it is confined to positive integral values of the exponent, since otherwise the process of performing the multiplication would be impossible. For such exponents it was known to the Arabs in the twelfth century and to the Chinese in the fourteenth century. In the form given in this dictionary and in many of our modern text-books it was known by H. Briggs (1556–1636), who died before Newton was born. Under the term "hexagram" it is called the "Pythagorean symbol." This symbol was the pentagram according to the "Manual of Greek Mathematics" by T. L. Heath, page 108, 1931.

Under the term "metacyclic" there appears the following sentence: "Denoting or pertaining to any permutation of elements in any given cycle of numbers."

If such a cycle would involve n numbers each of the possible $n!$ permutations of these numbers would be metacyclic according to the given definition. I know of no authority for the use of the common mathematical term "metacyclic" with this meaning and see no reason for using it thus. Under the term "Transitive group" it is stated that "if any set of n elements is replaced by any such set, it is *n-ply* transitive." If this were true it would follow that when a group of degree n is simply transitive it is also n-1 times transitive, which is obviously not necessarily true. In order that a group is *n-ply* transitive it is not sufficient that every set of n letters found therein is replaced by its substitutions by every other such set, but this replacement must occur also in every possible order. The fact that this distinction is frequently omitted elsewhere makes it the more desirable that it should be clearly given in a standard reference work.

Under the term "permutable" there appears the following sentence: "Leaving a finite group unchanged when it is operated upon by the group and the result is operated upon by the inverse of the original operation." It is difficult to see what is meant by operating on a group by the group. The term "permutable" is used in group theory with a wider meaning when it relates to groups than when it relates to operators. At any rate, the quoted sentence is practically meaningless but relates to an important mathematical property. Under the term "group of an equation" there appears the following statement: "A transitive substitution group, of the same degree as the irreducible equation, that does not change any function of the roots that is expressible rationally through the coefficients, but changes every other." The group of a reducible equation is intransitive and the definition of the term "group of an equation" should include this case. The definition of the preceding term, "group of a function," is also incomplete, since it applies also to every subgroup of this group.

In the biographical section which appears at the end of this dictionary the Hindu mathematician Aryabhata is said to be "the earliest known algebraist" and to have flourished in the fifth century, while Diophantus of Alexandria is called a "Greek algebraist" who flourished in the third century. It is obvious that it is impossible that both of these statements are correct. The well-known Norwegian mathematician Sophus Lie is here said to have died in 1870, when he was only twenty-eight years old. As a matter of fact most of his extensive works were published after this date, and he died in 1899 at the age of fifty-six years. One looks in vain in this section for the name of one of the most noted French mathematicians, E. Galois (1811–1832), whose fame has gradually increased since the time of his early death and has far outstripped that of many others whose names appear here.

G. A. MILLER

UNIVERSITY OF ILLINOIS

THE CHLORINE CONTENT OF THE LEDA CLAY

A SAMPLE of fossiliferous Leda clay (Pleistocene) collected in a road cut near Waterville, Maine, was recently analyzed by one of our students, U. U. Savolainen, of the Tufts College Chemical Department, for its chlorine content. The results, although provisional, indicate that further work along similar lines may prove of interest and of geologic value.

The sample analyzed was a light grey unweathered clay containing abundant, well-preserved shells of *Mytilus edulis*. Microscopic examination showed it to be made up largely of colloidal clay particles, although there was some rock flour associated with the finer material.

The specific gravity of the fresh clay, determined by the paraffin dip method, was found to be 1.88, while that of the dried clay was 1.47. From these figures the pore space was calculated to be about 41 per cent.

The chlorine content was found by leaching the finely divided clay with distilled water and titrating with silver nitrate solution, using potassium chromate as the indicator. The results obtained varied from .0000731 to .0000789 grams of chlorine per gram of clay. From this and the pore space the possible amount of chlorine in the water that was assumed to have originally occupied the pore space was determined. This was found to be between .174 and .194 grams of chlorine per 1,000 grams of water.

At the present time the average amount of chlorine in sea water is about 19 grams of chlorine in 1,000 grams of water. Since the ratio of the chlorine to the total amount of salts in sea water is nearly constant, the chlorine found in the clay seems to indicate that the original sea water enclosed by the clay was about 1/100th of the average salinity of the present-day oceans. This low figure may be explained in several ways.

First of all, there is the ever-present possibility of error in the determination of such minute amounts of chlorine.

Secondly, there may have been some leaching of the chlorine content after the deposition of the clay. But this seems quite unlikely as indicated by the well-preserved shells of Mytilus.

Thirdly, there arises the possibility of chemical union or physical affinity of the chlorine with the clay constituents. How far this can take place, it is impossible to say.

Finally, there is the high probability of the original sea water being diluted by fresh water from rivers or melting ice. That this is quite likely is indicated by the presence in the clay of *Mytilus edulis,* which can withstand freshening of the water in which it lives. This species is frequently found living at the present time in large numbers far up estuaries that empty into the ocean along the coast of Maine.

ARTHUR S. KNOX

TUFTS COLLEGE

SOME OBSERVATIONS ON SLUMPING AND GULLY FORMATION

SOIL erosion and its prevention is an important problem to those interested in the conservation of our natural resources. In order to adequately solve the problem of soil erosion much information, obtained under various conditions, must be collected. Therefore, these observations are recorded as a contribution to the sum total of information already accumulated on this subject.

On the afternoon of Friday, October 9, 1936, in Muskingum County and neighboring portions of Ohio there occurred a severe rain-storm of the proportions of a cloudburst, which continued for perhaps one-half hour. After the torrent was over the rain continued to fall intermittently during the night. In the space of about 12 hours 4¼ inches of rain fell into a rain gauge just south of the village of New Concord, a large portion of which—perhaps as much as 3 inches—fell during the cloudburst.

On the campus of Muskingum College in New Concord there is a hill known as Flag Pole Hill which has been subject to severe slippage and gullying. The slipping was due to a clay layer about 11 feet above the Harlem coal and to another clay layer just below the coal. This hill had just been graded and manured in preparation for the planting of grass.

About one hour after the downpour the writer observed that a number of gullies had been formed by the run-off. When observations were first made a shallow gully with a funnel-shaped head 4½ feet across, narrowing to less than a foot, was observed. The head of the gully was just above the clay strata about 11 feet above the Harlem coal. In making the observations at this point the observer sank a foot or more into the mud. From time to time the water-soaked material above the head of the gully would slip into the gully and there mix with the water flowing in the gully. This material was of the consistency of a very viscous liquid, which could be seen to flow down the gully at the rate of a foot or less a minute. The advancing front of the sub-liquid mud measured at times an inch or two in height. Darkness terminated this observation, but early next morning the observations were continued.

During the night a slip 17 feet long had taken place on either side of the gully just described and at the level of the head of the gully. The slip had taken place when the soil and sub-soil above the clay had become saturated with water to the point that it could no longer hold together and slid down on the slippery clay strata. This slip extended 8 feet on one side and 9 feet on the other of the original gully. The material slipped down the hill for a distance of 3 feet and formed a terrace 2 feet high and 5 feet wide made up of soil and sub-soil which had slid down over the clay strata, which acted as a lubricant. Thus 170 cubic feet of material had moved 3 feet down the slope during and just after this one rain.

At the same level another smaller slip 26 feet in length had occurred but had moved down the hill only from 8 to 10 inches.

About 10 feet north of this large slip a large gully started about 13 feet below the top of the hill. From dimensions of a few inches it deepened and widened in the shaly sub-soil to 10 inches wide and 6 inches deep. On reaching the clay horizon it widened to as much as 22 inches and deepened to 8 inches or more. Several fall-like drops occurred in the bottom, as the water found more resistance in some layers than in others. At the level of the slip it widened to 4 feet, narrowing to about 30 inches in a distance of 5 feet, where it deepened to 18 inches. It has been calculated that this one gully alone has been formed by the moving of more than 60 cubic feet of material. This portion of the hillside can be classed as a "D" slope (more than 30 per cent.), from which most of the soil has been removed.

Other smaller gullies, 17 of which ranged upward to 7 inches in depth and 5 inches in width, were formed on this hillside during the few hours in which the water ran off during and immediately after the rain. These gullies were best developed in the clay below the outcrop of the Harlem coal. At one place where the hillside had been previously graded and was covered with a thick grass cover a slip 21 feet long had taken place on the clay just below the Harlem coal and slid 4 feet down the hill. The portion of the hillside in which this slip and the smaller gullies were developed can be classed as "C" slope (20 to 30 per cent.), from which most of the soil had been removed.

While the situation here described may not seem in itself important, yet when we consider that the erosion noted has taken place on a hillside having an area of less than one acre and during one rain the seriousness of the situation becomes evident.

ROBERT H. MITCHELL

MUSKINGUM COLLEGE

SKUNK MORTALITY ON THE HIGHWAY

DEAD animals on the highway have brought to the attention of the naturalist, amateur and professional, the tremendous toll of wild life taken by motor vehicles.

Because of the seemingly unusual abundance of freshly killed skunks, *Mephitis mephitis*, on the highways recently, tabulations were made on three rides of approximately 200 miles each. These counts, the dates and the routes are given in Table 1 for whatever interest or value they may have for readers of SCIENCE.

All rides and observations were made in daylight; all the dead animals observed were readily identified, not having been crushed or otherwise sufficiently mutilated to destroy outstanding characteristics.

TABLE 1

Dead skunks	Date	Route
6	9/21/36	Belvidere, N. J., to Washington, D. C., *via* Allentown, Pottstown and Oxford, Pa., and Baltimore, Md.
11	9/22/36	Washington, D. C., to Parsons, W. Va., *via* Winchester, Va., Romney, W. Va., and Redhouse, Md.
5	9/24/36	Bangor, Pa., to Washington, D. C., *via* Allentown, Harrisburg and Gettysburg, Pa., and Frederick, Md.

As impressive was the complete absence of other dead animals.

B. H. WILFORD
J. F. WILFORD

ASHEVILLE, N. C.

SPECIAL CORRESPONDENCE

THE McDONALD OBSERVATORY

THE construction of the 82-inch reflector of the McDonald Observatory of the University of Texas is nearing completion. The mounting is installed in the dome on top of Mount Locke, near Fort Davis, Texas, and the large mirror is now being parabolized by Mr. C. A. R. Lundin in the optical shops of the Warner and Swasey Company in Cleveland. The mounting, designed by Mr. E. P. Burrell, director of engineering of the Warner and Swasey Company, meets all specifications. The telescope drive was built under Mr. Burrell's supervision by the General Electric Company and resembles the Hulburt-McMath drive developed at the Lake Angelus station of the University of Michigan.

Under the supervision of Dr. G. W. Moffitt, several accessory instruments have been built in the shops of the Yerkes Observatory, mostly by Mr. C. Ridell and Mr. H. Foote. A Cassegrain spectrograph with quartz and glass optics, using a 500 millimeter U.V. camera and two Schmidt cameras of 180 millimeters and 90 millimeters foci, is nearly completed. Practically all the lenses, including those for a slitless spectrograph as well as a large zero-corrector, were computed by Dr. F. E. Ross. To Dr. Ross's skill as an optical designer, the success of these instruments will, in no small measure, be due.

The construction of offices in the lower part of the dome, residences for the staff, a power plant and other subsidiary buildings, under the supervision of Mr. W. W. Dornberger, architect of the University of Texas, will be completed before the end of this year. The continued active interest on the part of the authorities of the University of Texas, principally of President H. Y. Benedict and of Mr. J. H. L. Stark, chairman of the Board of Regents, has made it possible to complete these building operations in time for the rigorous tests which will be made after the mirrors have been shipped to Mount Locke.

The University of Chicago, cooperating in this project with the University of Texas, has for more than two years maintained a small staff of workers on Mount Locke. Dr. C. T. Elvey, assistant professor of astrophysics in the University of Chicago, and Dr. F. E. Roach have made a series of photoelectric observations of the brightness of the night sky and of a number of eclipsing variables. They have also made observations of the color of sunlight seen through a clear, a dusty and a foggy atmosphere. The discovery of a surprisingly large excess of diffuse light in low galactic latitudes, after full account has been taken of the direct light of unresolved faint stars in the Milky Way, is one of the outstanding results of this work. It suggests the existence of extended nebulous regions over large parts of the galactic zone, similar perhaps to the "luminous films" found by Barnard on many of his photographs. Other results, by Struve, Elvey and Roach, were obtained with a new f/2 Schmidt camera. They include the determination of the colors of reflection nebulae and the detection of radial polarization in one of the nebulae.

The scientific staff of the McDonald Observatory has now been completed by the University of Chicago. Dr. Carl K. Seyfert, of the Harvard Observatory, and Dr. Paul Rudnick, of the University of Chicago, have been appointed astronomers. Mrs. Jessie Rudnick, M.S. in astronomy, will serve as part-time assistant. Dr. Elvey will continue to supervise the activities of the observatory during the absence of the director.

In order to make the most efficient use of the equipment on Mount Locke, and in accordance with the spirit of the agreement between the University of

Texas and the University of Chicago, President Hutchins and the Board of Trustees of the University of Chicago have decided to strengthen the department of astronomy and astrophysics by the appointment of several new members. Dr. G. P. Kuiper, formerly of the University of Leiden and of the Lick Observatory, joined the staff at Williams Bay on September 1. Dr. Kuiper is known for his studies of double stars and for the discovery of several "white dwarfs." He expects to start, after January 1, a series of observations of double stars with the 12-inch telescope of the Yerkes Observatory, which is now temporarily mounted in Texas. Dr. B. Strömgren, formerly of the University of Copenhagen, began, on October 1, a course of lectures on astrophysics at the University of Chicago. Dr. Strömgren is interested, among other things, in the interpretation of the Russell-Hertzsprung diagram; he plans to spend a part of his time in Williams Bay. Dr. S. Chandrasekhar, of Madras, India, and more recently of Cambridge University and Harvard, will commence work at the Yerkes Observatory on January 1, 1937. Dr. P. C. Keenan, who has rejoined the Yerkes staff after a year's absence, will cooperate with Dr. W. W. Morgan in a study of the luminosities and physical characteristics of the stars. It is expected that the old, as well as most of the new, members of the staff will make periodic trips to Mount Locke to secure observational material with the large reflector.

OTTO STRUVE

YERKES OBSERVATORY
WILLIAMS BAY, WIS.

SPECIAL ARTICLES

MATHEMATICAL EXPRESSION OF EQUILIBRIUM BETWEEN NITROGEN AND PHOSPHORIC ACID IN PLANTS

IT has been known for nearly half a century that phospholipins (phosphatides) found in all cells play a predominant rôle in the physiological processes involved in growth and reproduction. In some plant species phospholipins were found to vary directly with the protein-N and in others with the amide-N.[1]

With the growth of conviction among biologists that the final truth of a phenomenon lies in the mathematical description of it, mathematical expressions for the physiological relationships between the various elements ("entities") and plant response to them have been sought,[2] expressible in terms of simple laws.[3]

In investigations now under way in this laboratory on the influence of the soil and the weather on the action of fertilizers by means of periodic analysis of leaves of the same metabolic age (foliar diagnosis) certain plots of Tier 1, Section B, of the long-continued vegetable fertility plots of the Department of Horticulture, on which potatoes were growing in 1935, have been examined. Plot 15, which has received partly rotted horse manure at the rate of thirty tons per acre, has continuously given the highest yields on this particular tier. In 1935 the yield of tubers was 196 pounds per 1/100th acre plot. The plants growing on this plot, therefore, may be regarded as well nourished and nearing the optimum for the soil and climatic conditions in this region.

In Fig. 1 are plotted as ordinates and abscissae,

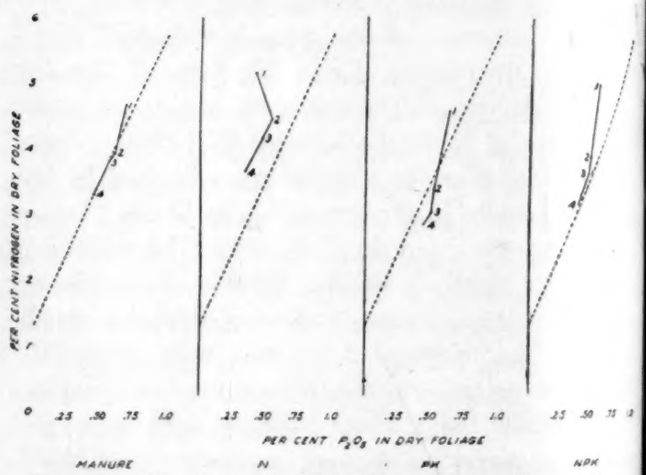

FIG. 1. Showing the deviations from the optimum physiological balance between nitrogen and phosphoric acid in four differently treated plots.

respectively, the data for the chemical analysis for total nitrogen (N) and total phosphoric acid (P_2O_5) of the fourth and fifth leaves taken from plants growing on this manure plot (Plot No. 15) and also from three plots treated with commercial fertilizers; namely, nitrogen alone (Plot No. 2), phosphate + potash (Plot No. 8) and nitrogen + phosphate + potash (Plot No. 10). The numerals 1, 2, 3, 4 indicate, respectively, the coordinate points for each of the sampling dates—July 7, July 29, August 9 and August 24, 1935.

The broken line has been drawn by joining the coordinates (given in columns 1 and 2, Table 1) for the third and fourth samplings, taken on August 9 and August 24, respectively, of leaves of the same physiological age of plants growing on the manure plot. The scale for P_2O_5 is twice that for N. *The equation to this line is* $y = 2.2x + 1.31$. The ordinates of this line corresponding to the amounts of P_2O_5

[1] F. Czapek, "Biochemie der Pflanzen," Zweite Auf, pp. 772–773, Jena, 1913.

[2] Walter Thomas, SCIENCE, 70: 382–384, 1929.

[3] H. Lagatu and L. Maume, *Compt. Rend.*, 180: 1179, 1925.

found by analysis at successive sampling dates vary very little from the amounts of N found experimentally. The deviation of experimental values calculated from the above equation is shown in the last column of Table 1.

TABLE 1

EXPERIMENTAL VALUES FOR P_2O_5 AND EXPERIMENTAL AND CALCULATED VALUES FOR N IN DRY FOLIAGE AT FOUR SAMPLING DATES FOR PLANTS GROWING ON THE MANURE PLOT

Dates of sampling	Experimental values		Calculated values	Relative deviation
	P_2O_5 (E_x)	N (E_y)	N (E_{y_1})	$\frac{E_y - E_{y_1}}{E_y}$
	Per cent.	Per cent.	Per cent.	Per cent.
July 7 ...	0.688	4.650	4.340	+0.067
July 29 ...	0.608	3.920	3.980	−0.015
Aug. 9 ...	0.564	3.790	3.790	0
Aug. 24 ...	0.448	3.280	3.280	0

On the first sampling date (July 7), nitrogen in this manure plot is somewhat in excess in relation to the optimum value; a result which can be accounted for by an excess absorption of nitrogen caused by the intervention of nitrogen produced by nitrification in a favorable season from the cover crops used in the rotational system. On the second (July 29), third (August 9) and fourth (August 24) sampling dates equilibrium between N and P_2O_5 is attained.

The yields of tubers from the three other plots are: N (Plot No. 2) 109 pounds, PK (Plot No. 8) 148 pounds and NPK (Plot No. 10) 163 pounds per 1/100th acre plot. The deviation from the optimum (broken) line with respect to position, form and length between sampling dates shows in each case the nature of the disequilibrium between N and P_2O_5 in the plants growing on the particular plot and may be regarded as an indicator of the lack of physiological balance between nitrogen and phosphorus. Details will be published elsewhere.

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RAMAN SPECTRA OF AMINES AND METHYLATED AMMONIUM IONS

FROM the point of view of the electronic theory of valence, the ammonium ion is an exact analogue of methane, the methylammonium ion of ethane, the tetramethylammonium ion of tetramethyl methane, and so forth. Thus two systems of analogous compounds exist. Since ammonium ions can exist only in association with a suitable anion as salts, most of the physical properties of the latter are very different from those of the analogous hydrocarbons. Study of Raman spectra, however, reveals directly the intimate relation between the two series of compounds, for the spectra of the substituted ammonium halides are produced only by the vibrating cations, the isolated halide ions containing no covalent bonds and therefore giving rise to none of the observed vibrations. It should thus be expected, and has been experimentally found, that the spectra of the ammonium chlorides, from the monomethyl to the tetramethyl derivative, are completely analogous to those of the corresponding hydrocarbons from ethane to tetramethyl methane, which have been studied by other investigators.[1, 2, 3] If CH_3 and $^+NH_3$ groups be regarded approximately as single vibrating units, then these compounds possess certain well-known types of symmetry and should give rise to a few simple fundamental vibrations. The methyl ammonium ion, for instance, behaves similarly to a diatomic molecule and gives rise to a powerful valence vibration involving the C–N^+ bond. The observed fundamental vibrations (which lie in the region below 1,050 cm^{-1}) are as follows (the assumed geometrical pattern of each ion is given in parentheses, following its designation):

Methylammonium chloride (linear "diatomic" ion): 995 (6). (Compare ethane.)

Dimethylammonium chloride (symmetrical bent "triatomic" ion): 412 (2) (P); 895 (4) (P); 1029 (2) (D). (Compare propane.)

Ethylammonium chloride (unsymmetrical bent "triatomic" ion): 411 (2); 873 (5); 1047 (4). (Compare propane.)

Trimethylammonium chloride (Trigonal pyramid): 406 (1) (D); 468 (1/2) (P); 821 (5) (P); 987 (4) (D). (Compare isobutane.)

Tetramethylammonium chloride (regular tetrahedron): 372 (1) (D); 455 (2) (D); 752 (6) (P); 955 (6) (D). (Compare tetramethyl methane.)

Trimethylamine oxide hydrochloride (Trigonal pyramid): 382 (3); 500 (2); 754 (7); 947 (7). (Compare tert-butyl alcohol.)

The number in parentheses following the frequency of each line indicates its roughly estimated relative intensity. Some qualitative polarization measurements have also been made; P denotes a strongly polarized line, ($\rho << 6/7$), D a nearly depolarized line ($\rho = 6/7$). Analysis of the observed spectra indicates that they are in harmony with expectations from the structures assumed, and comparison with the corresponding hydrocarbons indicates that the C–N^+ bond is somewhat stronger than the C–C bond.

These compounds of course yield numerous Raman frequencies above 1,050 cm^{-1}, owing to the presence of numerous C–H and $^+$N–H bonds. The free amines

[1] K. W. F. Kohlrausch and F. Köppl, *Zeits. physik. Chem.* (*B*), 26: 209, 1934.

[2] D. H. Rank, *Jour. Chem. Physics*, 1: 572, 1933.

[3] R. Ananthakrishnan, *Proc. Indian Acad. Sci.* (Bangalore), 3(A): 527, 1936.

corresponding to most of these ammonium salts have also been studied in aqueous solution, and many new Raman lines in addition to those previously recognized[4] have been found. The detailed discussion of these spectra is necessarily somewhat complex and will be presented elsewhere, but one significant point may be reported here. Free primary and secondary amines give one (or two) powerful Raman lines between 3,300 and 3,400 cm^{-1}, presumably associated with the un-ionized N–H linkage; the corresponding ammonium salts, however, in which the amino group has acquired a proton, show no Raman frequencies above 3,050 $cm.^{-1}$ Likewise the sodium salts of glycine and alanine show strong lines near 3,330; the isoelectric amino acids show no lines above 3,030. The conclusion follows that the amino group in glycine and alanine must be electrically charged; in other words, that these amino acids exist as dipolar ions at the isoelectric point. This supplements the earlier spectroscopic proof of this structure,[5] based on studies of the ionization of the carboxyl group. Ample evidence for the theory of dipolar ions has been forthcoming from other sources, but the evidence from Raman spectra is valuable for the clarity and directness of the proof it offers for the validity of this structure. This method also should be directly applicable to the determination of structure in new compounds containing these ionizable groups.

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RECOVERY OF VIABLE ADRENAL CORTICAL TISSUE[1]

IT has been reported by Ingle[2] that autogenous transplants of the adrenal glands to the ovaries in rats consistently become established as functional grafts. On the other hand, direct homoplastic transplants of the adrenal glands of adult rats invariably have degenerated. It was suggested by one of us (Nilson) that acclimatization of transplanted glands may be a function of genetic similarity and that the survival of homoplastic transplants could be used as an index for determining homozygosity in inbreeding experiments.

The following preliminary experiments were carried out with female rats obtained from two inbred strains of pied rats segregated for differences in rate of growth and efficiency of utilization of feed.[3] Cross-strain transplants of the adrenal glands to the ovaries were made in four pairs of rats and all died of adrenal insufficiency within sixty days after operation. The adrenal glands were also exchanged between six pairs of sisters belonging to the high efficiency strain. Functional grafts were established in nine of the twelve animals. Histologic examination of the grafts sixty days after operation disclosed good regeneration of the adrenal cortical tissue. In a third experiment the adrenal glands were exchanged between four pairs of sisters belonging to the low efficiency strain. Functional grafts were established in three of these eight animals, as was demonstrated by histologic examination.

All completely adrenalectomized rats prepared in this laboratory die of adrenal insufficiency when fed a diet high in potassium and low in sodium chloride. Only animals which receive replacement therapy or which have viable adrenal cortical tissue in addition to accessory glands survive for as long as sixty days after operation. Our evidence on survival time in addition to our histologic evidence is proof that some functional grafts were established between siblings of inbred strains of rats. A detailed study of the influence of genetic relationship of the donor and the host on the success of homoplastic transplantation of adult adrenal glands in the rat is being carried out in this laboratory.

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[4] K. W. F. Kohlrausch, "Der Smekal-Raman Effekt," Berlin, 1931, pp. 311–312. New data on anhydrous liquid amines by Kohlrausch, *Monatsch. Chem.*, 68: 349, 1936.

[5] J. T. Edsall, *Jour. Chem. Physics*, 4: 1, 1936. See also M. Freymann and P. Rumpf, *Jour. Phys. Radium*, 7: 30, 1936.

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[2] D. J. Ingle and R. F. Harris, *Am. Jour. Physiol.*, 114: 657–660, February, 1936.

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